ISCTE IUL
REPOSITÓRIO
INSTITUTO UNIVERSITÁRIO DE LISBOA

Repositório ISCTE-IUL

Deposited in *Repositório ISCTE-IUL*:
2018-06-05

Deposited version:
Post-print

Peer-review status of attached file:
Peer-reviewed

Citation for published item:
Teixeira, J. P., Matos, S. A., Costa, J. R., Nachabe, N., Luxey, C., Titz, D....Gianesello, F. (2017). Transmit array as a viable 3D printing option for backhaul applications at V-band. In 2017 IEEE International Symposium on Antennas and Propagation & USNC/URSI National Radio Science Meeting. (pp. 2641-2642). San Diego: IEEE.

Further information on publisher's website:
10.1109/APUSNCURSINRSM.2017.8073363

Publisher's copyright statement:
This is the peer reviewed version of the following article: Teixeira, J. P., Matos, S. A., Costa, J. R., Nachabe, N., Luxey, C., Titz, D....Gianesello, F. (2017). Transmit array as a viable 3D printing option for backhaul applications at V-band. In 2017 IEEE International Symposium on Antennas and Propagation & USNC/URSI National Radio Science Meeting. (pp. 2641-2642). San Diego: IEEE., which has been published in final form at https://dx.doi.org/10.1109/APUSNCURSINRSM.2017.8073363. This article may be used for non-commercial purposes in accordance with the Publisher's Terms and Conditions for self-archiving.

Use policy

Creative Commons CC BY 4.0
The full-text may be used and/or reproduced, and given to third parties in any format or medium, without prior permission or charge, for personal research or study, educational, or not-for-profit purposes provided that:

- a full bibliographic reference is made to the original source
- a link is made to the metadata record in the Repository
- the full-text is not changed in any way

The full-text must not be sold in any format or medium without the formal permission of the copyright holders.

Serviços de Informação e Documentação, Instituto Universitário de Lisboa (ISCTE-IUL)
Av. das Forças Armadas, Edifício II, 1649-026 Lisboa Portugal
Phone: +(351) 217 903 024 | e-mail: administrador.repositorio@iscte-iul.pt
https://repositorio.iscte-iul.pt

Transmit Array as a Viable 3D Printing Option for Backhaul Applications at V-band

Jorge P. Teixeira, Sérgio A. Matos, Jorge R. Costa
Instituto de Telecomunicações, Instituto Universitário de Lisboa, (ISCTE-IUL), Lisbon, Portugal.
Jorge_Pedro_Teixeira@iscte.pt

Nour Nachabe, Cyril Luxey, Diane Titz
EpOC, Université Nice-Sophia,
Valbonne, France

Carlos A. Fernandes
Instituto de Telecomunicações, Universidade de Lisboa
Lisbon, Portugal

Frederic Gianesello
STMicroelectronics,
Crolles, France

***Abstract*— Two designs of high gain dielectric lens for a V-band backhaul antenna, compatible with 3D printing, are compared. The available printing materials still have significant losses, which limit the performance of traditional focusing dielectric lenses, as the dome elliptical lens. Herein, we show that an all-dielectric transmit array can present several mechanical and electrical advantages, especially when high gains are required. We demonstrate that even with a compact transmit array ($F/D = 0.67$) it is still possible to comply with the usual bandwidth (57-66 GHz) and gain (>30 dBi) requirements for backhaul applications.**

Keywords—Transmit array, Dome elliptical lens, 3D printing, backhaul, millimeter wave

I. INTRODUCTION

3D printing is becoming an enabling technology for antenna design. In particular, this technology can be a cost-effective option for Millimeter-Wave backhaul applications [1]. Low-cost, high performance Radio Frequency Integrated Circuit (RFIC) can operate beyond 100 GHz. The burden is still on the antenna design that has to conciliate low cost with high gain, large bandwidth and terminal's compactness. For a backhaul wireless connection at 60 GHz, a minimum of 30 dBi gain between 57 GHz and 66 GHz is required. Lens-based solutions allow integrating RFIC as the feed of the antenna [2].

In this communication, a dome elliptical lens [3] and an all-dielectric transmit-array are compared as possible antenna solutions for this type of applications. The dome elliptical lens provides the best directivity and bandwidth performances. However, this lens tends to be bulky and have low radiation efficiency caused by material losses. For example, for PLA ($\varepsilon_r = 2.98, \tan\delta = 0.015$), which was the printing material considered herein, we obtain more than 3 dB of losses on the lens. On the other hand, a transmit-array is more compact and can provide higher radiation efficiency using the same material. However, to achieve competitive directivity and bandwidth performances a minimum F/D (ratio between focal distance and the aperture diameter) is required, impacting on the terminal height. The same feed was considered in both lenses: a 13 dBi gain horn antenna that mimics the gain obtained by the RFIC 2x2 array solution presented in [3]. We show that there is a cross point in terms of antenna size at which the transmit-array offers significant mechanical and electrical advantages. We should stress that similar conclusions could be obtained if other feeds or 3D printing materials were considered. Increasing the feed directivity will result in a better performance of the transmit array as it increases the F/D ratio, however, it also implies increasing the antenna height.

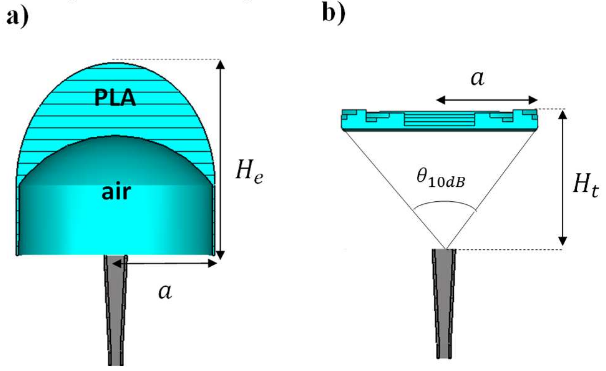

Fig. 1. Section view of the two antenna solutions. Both solutions have the same radius $\boldsymbol{a}$: (a) dome elliptical lens and (b) transmit array (b).

II. COMPARISON BETWEEN THE TWO LENS SOLUTIONS

The dome elliptical lens geometry can be defined by knowing it's radius and the material permittivity, according to the design rules presented in [4] . However, as in [3], a spherical air dome concentric with the ellipse focal point is opened. By doing so the material losses are significantly reduced with minimal perturbations in the lens far field radiation pattern. The transmit array, on the other hand, is composed by concentric rings with different heights d. This lens can be classified as a transmit array as it follows the usual design procedure based on frequency selective surfaces (FSS) and on the assumption of local periodicity [5]. In Fig. 2 we show that a complete 360º phase shift cycle at 60 GHz, with reasonable transmission, can be obtained by varying the height d of the FSS rings between 1 mm and 7.6 mm. For a given lens radius r the ring's height d is set according to the usual spherical-to-plane wave phase correction function (considering a 360º phase wrapping)

$$\Delta\emptyset_{lens}(r) = k_0\sqrt{r^2 + F^2} \qquad (1)$$

Where k_0 is the free-space wave vector at 60 GHz and F is the focal distance. The chosen granularity of the lens rings radius is Δr=2.5 mm ($\lambda/2$ at 60 GHz). The usual 10 dB edge tapering at the transmit array was considered as it provides the best aperture efficiency [6], which for a 13 dBi feed ($\theta_{10dB} = 40°$) corresponds to $F/D = 0.67$.

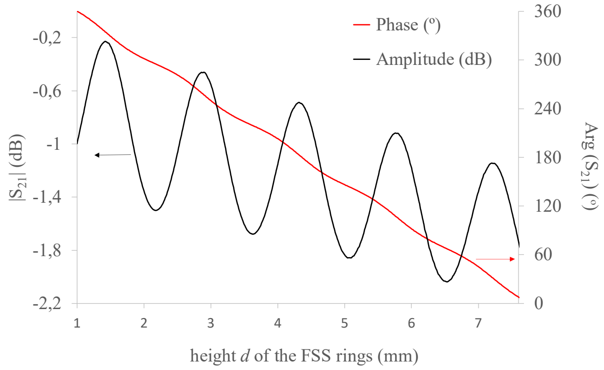

Fig. 2 – Transmission characteristic of the FSS as function the its height.

In Fig. 3 the directivity and gain of the two solutions are represented versus the lens radius for 60 GHz. For the radius $a = D/2 = 40\ mm$ the gain of the dome elliptical lens is 30.2 dBi and the height is $H_e = 77$ mm, whereas the transmit array provides 30.1 dBi of gain with $H_t = 61$ mm. Moreover, the transmit array has only 32% of the total mass of the dome elliptical lens (110 g). Above this radius value (corresponding to the aforementioned cross point) the transmit array achieves higher gains than the dome elliptical lens. From Fig. 3 it is clear that the radiation efficiency is the factor that limits the performance of the dome elliptical lens. For the transmit array the radiation efficiency was always above 83 %.

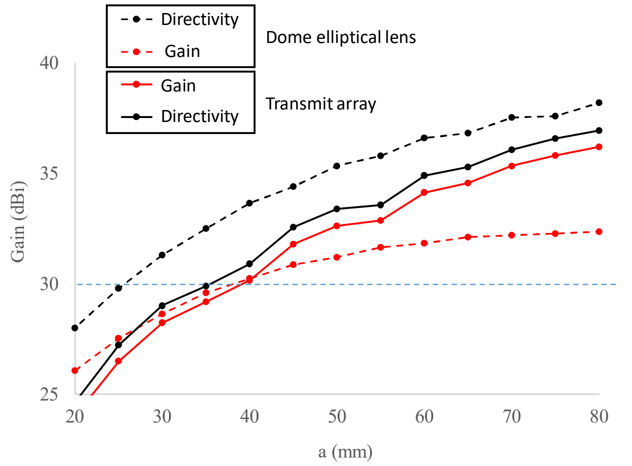

Fig. 3. Gains and directivities of the dome elliptical and transmit array lenses as function of the antenna radius for 60 GHz.

However, the transmit array has a more limited bandwidth response than the dome elliptical lens due to the 360 phase wrapping process. We can improve this response by increasing the focal distance, which corresponds to increase the feed directivity. For the same radius as before, i.e., $a = 40\ mm$, the gain at 57 GHz and 66 GHz with $F/D = 0.67$ is 28.9 dBi and 31.2 dBi, respectively, whereas for $F/D = 1$ (implying a 15 dBi horn illumination), only varies between 30.4 dBi and 31.5 dBi. However, for $F/D = 1$ the antenna height is $H_t = 88$ mm.

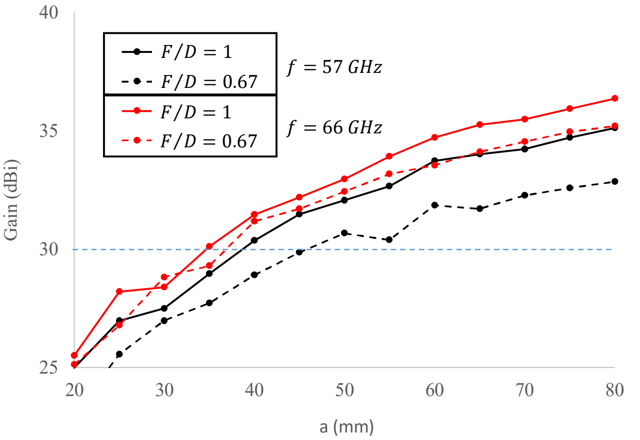

Fig. 4. Gain of the transmit array considering a $\boldsymbol{F/D}$ ratio of 1 (solid lines) and 0.67 (dashed lines) as function of the antenna radius for 57 GHz (black lines) and 66 GHz (red lines).

III. CONCLUSIONS

In this communication it is considered two possible lens designs for a backhaul connection at 60 GHz that are compatible with low cost 3D printing. We compare the more traditional dome elliptical lens with the performance of all dielectric transmit array. Taking into consideration that the current 3D printing materials have significant losses, we show that the transmit array can be a more suitable solution. We also quantify the trade-off between bandwidth and antenna height when using a transmit array. A transmit array with a 40-mm radius achieves a 30 dBi gain at 60 GHz (the same gain obtained with the dome elliptical lens) with a more compact height (61 mm versus 77 mm) and lighter (35 g versus 110 g) structure. For higher radius, the transmit array also has a better gain performance than the dome elliptical lens solution.

REFERENCES

[1] F. Gianesello, A. Bisognin, D. Titz, C. Luxey, C. A. Fernandes, J. R. Costa, and D. Gloria, “3D Printing Technology: Enabling Innovative & Cost Effective Industrial Antenna Solution,” in International Workshop on Antenna Technology (iWAT),Cocoa Beach, United States, March 2016.

[2] A. Bisognin, D. Titz, C. Luxey, G. Jacquemod, R. Pilard, F. Gianesello, D. Gloria, C. Laporte, H. Ezzedine, J. R. Costa, E. B. Lima and C. A. Fernandes and F. Devillers, “Millimeter-Wave Antenna-in-Package Solutions for WiGig and Backhaul Applications,” in International Workshop on Antenna Technology (iWAT), Seoul, South Korea, March 2015.

[3] Aimeric Bisognin, “Évaluation de technologies organiques faibles pertes et d’impression plastique 3D afin de contribuer au développement de solutions antennaires innovantes dans la bande 60 GHz – 140GHz,” Ph.D. dissertation, STIC, Universite De Nice-Sophia Antipolis, Nice, France, 2015.

[4] C. A. Fernandes, J. R. Costa, E.B. Lima, “Dielectric Lens Antennas,” in *Handbook of Antenna Technologies*, Zhi Ning Chen, Ed. Springer, 2016.

[5] D. M. Pozar, S. D. Targonski, and H. D. Syrigos, “Design of millimeter wave microstrip reflectarrays,” *IEEE Trans. Antenna Propag.*, Vol. 45, No. 2, pp. 287–296, Feb. 1997.

[6] P.F. Goldsmith, "Radiation Patterns of Circular Aperture with Gaussian Illumination," *Int. J. Infrared and Millimeter Waves*, vol 8, pp. 771-781, 1987.